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NATICK/TR-90/043

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OPTICAL TRANSMISSION PROPERTIES OF SELECTED SHELTER MATERIALS

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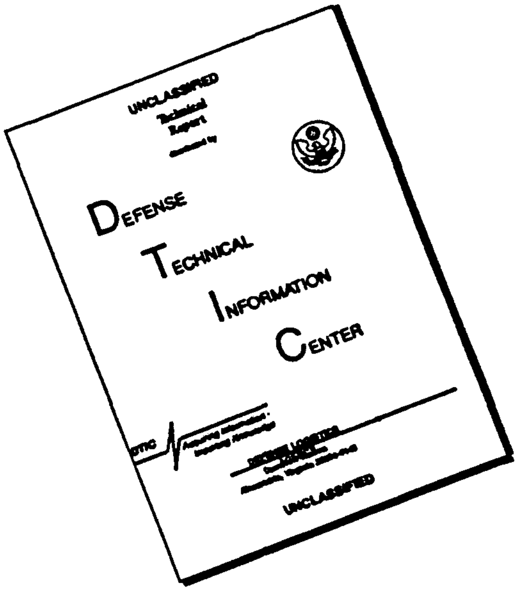

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Eight candidate tentage fabrics were evaluated for blackout (opacity to light transmission at night) in the laboratory and in the field with both incandescent and fluorescent lighting. A good correlation was obtained. Of the candidates examined, only the Hypalon-coated fabrics showed satisfactory blackout properties for visible and nonvisible wavelengths. The standard cotton duck (MIL-C-43627) was satisfactory only for visible radiation.

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PREFACE

The data for this report were collected by investigators from the U.S. Army Natick Research, Development and Engineering Center (Natick) from 1 June 1988 to 1 September 1988. This report describes tentage fabrics and their evaluation for opacity to light transmission at night in the laboratory and in the field. The investigation was conducted by the Individual Protection Directorate (IPD), Natick, under project number D-429-E.

Citation of trade names in this report does not constitute an official endorsement or approval of the use of such items.

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OPTICAL TRANSMISSION PROPERTIES OF SELECTED SHELTER MATERIALS

INTRODUCTION

A critical factor in the detectability of a tent at night is its "black out" capability, that is, its opacity when lighted from within. The current requirement for a "black out" test is the Test and Evaluation Command (TECOM) Field Test (TOP 10-2-175). This test was formulated during the 1940's before the advent of night-vision devices (night-vision goggles and the Starlight Scope). The test involves the assembling of two, or, preferably, a group of observers with 20/20 vision and depends on their judgment about the opacity of a complete tent when observed at various distances on a moonless night. Also, there is no distinct pass or fail criterion in this subjective, human-perception test in which incandescent lighting is used.

One of the otherwise promising TEMPER (Tent, Extendable, Modular, Personnel) tent fabrics (MIL-C-44103), Tan 459, being developed for the Aero-Mechanical Engineering Directorate (AMED) of U.S. Army Natick Research, Development & Engineering Center by the Individual Protection Directorate (IPD), showed an objectionable "glow," that is, excessive light transmission, when the tent interior was lighted. The tent was clearly visible to the unaided eye, even when a flashlight was substituted for the usual light source. The same base fabric (100% Polyester Duck) in Green 483 did not show this "glow."

Using a photometer, the optical transmission of several tentage fabrics was measured in the laboratory and the results were correlated with field tests as an aid in establishing realistic blackout test methods and specifications. A preliminary investigation indicated the transmittance problem is probably in the coating formulation, and not in the degree of dullness of the underlying polyester fiber, which was the same in both fabrics.

From the technical point of view, one was faced with the measurement of very low levels of illumination (opacity being only a relative property*) and measurement at wavelengths beyond the visible spectrum, especially at near-infrared wavelengths, at which image intensifier devices operate.

There was also the consideration that the tents are often lighted by fluorescent sources, all of which have spectral power distributions with a considerable amount of light energy at ultraviolet wavelengths, well below the visible spectrum. This radiation is also picked up by the widely used Generation II night-vision devices.

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*A few light photons get through, although in some cases not enough or of the wrong wavelength for the human eye to detect. These few photons are detected by image intensifiers and photomultiplier tubes, however, because the latter are multiplying devices, and their response is not that of the human eye.

Preliminary testing indicated the need for acquiring a photometer system that would meet the following requirements: A sensitivity of at least 10^{-8} footlamberts; and the capability of the photomultiplier tube of the photometer system to gather light energy from about 350 nanometers (nm) in the ultraviolet to about 900 nm in the near infrared. (Visible wavelengths lie between about 400 and 750 nm; the sensitivity of the human eye peaks at about 550 nm.)

Ordinary laboratory photometers are restricted to the visible wavelength range and have a sensitivity of not more than about 0.1 footlambert. It was not known if the transmission properties of the various fabrics at visible wavelengths paralleled those at near-infrared or ultraviolet wavelengths. It was conceivable that a fabric could be satisfactorily opaque at visible wavelengths but unsatisfactory at near-infrared wavelengths.

A photometer system suitable for the job was acquired from EG&G Gamma Scientific and consisted of the following components:

a. Photomultiplier detector, of spectral range 200-930 nm (nominal), equipped with several filters; "Photopic" (to simulate the response of the human eye), and three neutral density filters.

b. "High Efficiency" telescope, to gather radiant energy from one foot to infinity.

c. Digital radiometer, of sensitivity 10^{-7} footlamberts (nominal), capable of being calibrated in the photopic mode.

d. Standard light source, with lamp monitor and control, used for photopic calibration.

The advantage of laboratory measurements was that one could make some judgment about blackout effectiveness of the various fabrics without having to fabricate entire tents, or conduct the involved TECOM Field Test. A contractor could use such a test for experimentation purposes and the test could serve as a basis for Standard Federal Test Methods.

EXPERIMENTAL METHOD

Laboratory Test Method

The photometer system was calibrated according to the manufacturer's instructions. The instrument was used with a collection aperture of six-minutes' field of view. The test apparatus consisted of the photometer system, a "black box," and an 100 watt incandescent bulb (nominal) placed one foot from the sample. The box was made of plywood, and all interior surfaces painted in a matte black. The sample to be measured was placed on one side of the "black box," and was about 24 inches from the detector surface. Readings were taken in the "photopic" mode (visible spectral range, approximately 400-750 nm) and in the "open" mode* (the full spectral range). The test setup is shown in Fig. 1.

* The phototube surface is rated for 200-930 nm spectral response. The presence of a glass lens in the telescope restricts the UV response to about 350 nm.

Field Test Methods

Blackout testing of the various fabrics was conducted in the laboratory during the summer of 1988, and in the field on 3 Aug and 9 Aug 88, and the results compared. A list of the fabrics tested is given in Table 1. An additional sample similar to No. 16, a Nuclear, Biological, Chemical (NBC) protective film printed with a 4-color camouflage pattern, was tested in the laboratory (but not in the field).

D. Stewardson of the Tentage Section (TS), AMED, arranged and coordinated the field testing which consisted of observation of actual tent sections constructed of the fabrics described in Table 1.

A Standard Integrated Command Post Shelter (SICPS) was assembled. Three of the walls were constructed of MIL-C-44103, coated polyester duck in Camouflage Green 483. A variety of sample panels (10 ft. x 8 ft.) was prepared for use as the fourth wall (Table 1). The panels were prepared for easy mounting over the fourth wall in a manner that permitted very little light leakage.

The tent was erected at the Sudbury Training Annex on the edge of a large field with mixed vegetation to its rear. The test wall was positioned so observers could view the panel at a variety of premeasured distances up to 300 meters. All observations were made under moonless conditions by the following IPD and AMED personnel:

IPD

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The interior of the tent was illuminated by a Bruce Lamp Set (Light Set for Temper LP-PDES4-83, two, 40-watt fluorescent bulbs) and a 100-watt incandescent bulb positioned in the center of the panel, 0.3 meter from the wall. The lamps could be turned on or off, independently, by persons stationed outside the tent.

Premeasured viewing stations were established at distances of 25 meters, 50 meters, 100 meters, 150 meters, 200 meters, and 300 meters. The observation posts were positioned perpendicular to the test panel and each permitted an unobstructed view of the wall. At the end of the systematic viewing, all of the fabric samples were ranked visually, with and without image intensifiers, from a distance of 200 meters.

The observation team and the light-control groups communicated by "walkie-talkie" radio. Visual observations were made only after the viewing team had time to accommodate their eyes to the darkness. In order to maintain their night vision, observers were constantly reminded to keep flashlights off and to "look away" as panels were changed. Observations also were made using a pair of Night-Vision Goggles (AN/PVS5A), a Night-Vision Sight (AN/PVS-2), and a SECO NI-TEC image intensifier (NVS-100).

Observers were asked to complete a data sheet (Fig. 2) for each panel wall. Yes or no responses were required on whether light was seen visibly, or through an image intensifier. The radio communication allowed the observers ample opportunity to determine "on," "off" conditions for the Bruce and incandescent lamps. Visual observations were made at each station, followed by image intensifier scans. Observers also were asked to comment on the gloss, reflectance or any unusual characteristic noted during the exercise.

Still photographs were taken on both nights using a specially adapted camera mounted behind an image intensifier (the SECO device). Video recordings were made on the first night, but equipment problems prevented taping on the second night.

Results

The laboratory and field testing yielded the results given in Tables 2 and 3. Sample #16, the green-colored Nuclear, Biological, Chemical (NBC) Protective Film, was observed but not ranked in the field. At the time the field trials were conducted, this sample had not been measured in the laboratory. However, the film was observable, both visibly and by image intensifier, at all distances up to 300 meters, regardless of the type of light source used within the tent. Sample #16 behaved similarly to samples 2, 7, and 9 in the field tests. Printing of a 4-color disruptive (non-Woodland) camouflage pattern onto this substrate caused its laboratory transmission to decrease (as expected) from 0.542 (photopic) and 12.100 (open) to 0.210 and 6.540, respectively, for the tan portion of the camouflage pattern, the measurement being made with the pale green side closest to the light source.

In the field ranking of fabrics in the "open" mode, the various observers were able to agree only that samples 4 and 6 were "best," and 2 and 7 "poorest" in blackout performance. There was disagreement about ranking of the other fabrics between these two extremes.

Sample #7 (MIL-C-43006) was a lighter weight fabric than the others, so it was not surprising that it fared poorly.

Conclusions

Of the various fabrics tested, only the two Hypalon®-coated fabrics (samples 4 and 6) were satisfactory in blackout performance,

in the sense that regardless of the type of illuminant used within the tent, the tent was not visible to either the unaided eye or through night-vision devices at distances of 25 meters and greater (up to 300 meters).

The cotton duck (sample 3) was, to the same extent, satisfactory to the unaided eye, but not acceptable when viewed through night-vision devices. The remainder of the samples tested were, for the most part, detectable at 25 meters to 300 meters to the eye, as well as to the night-vision devices. The maximum range beyond which the various tentage materials are completely opaque, and undetectable to the eye or night-vision devices, remains to be determined. The field tests conducted at the Sudbury site were limited to 300 meters, because no cleared area of greater distance was available.

Only samples having a photopic mode reading of 0.001 foot lamberts or less are certain to provide adequate blackout properties in a tent fabric for visual sightings at distances up to 300 meters. Samples producing photopic readings between 0.001 and 0.002 may have adequate blackout properties, but this parameter could not be established from the small number of samples observed and tested. The one sample exhibiting a photopic reading of 0.002 footlamberts (Sample 1), was visually observable when illuminated from within by either a Bruce lamp or incandescent bulb, at all distances up to 150 meters, and even beyond, by at least one observer.

Test tentage samples measured in the "open" mode of the blackout test apparatus having readings greater than 0.014 watts/cm^2 /steradian were visible to night-vision devices at all distances observed, up to 300 meters, regardless of which test illuminant was used. Signatures might be observed at greater distances as well, but the maximum distance needs to be determined. From the samples tested, it can be assumed that a tentage fabric having an "open" mode reading of 0.014 watts/cm^2 /steradian, or less, will have adequate blackout properties to the threat of detection by night-vision devices. It is possible that a reading somewhere between 0.014 and 0.51 watts/cm^2/ steradian is the proper tolerance limit for opaqueness to a night-vision device, but the end-point must be determined by experimentation. It is only certain at this point that readings of 0.51 watts/cm^2 /steradian, or higher, for a tentage fabric measured in the "open" mode, will be detectable through a GENERATION II image intensifier at distances of 25 to 300 meters.

The field test results correlated quite well with the laboratory results, and gave confidence in writing a proposed federal test method based on the laboratory instrumentation. However, the critical threat distances remain to be determined. No account has been taken of other detectability factors, like gloss, shade contrast with the surroundings, etc.

In general, the incandescent lighting was more noticeable than that of the Bruce lamps. The incandescent brightness was more localized, whereas the fluorescent lamps illuminated the tent more or less uniformly.

Recommendations

Additional testing should be done at greater (and more realistic) distances, and the maximum range for blackout protection of specific types of tents needs to be defined.

All field tests were conducted with Generation II Night-Vision devices. Further tests utilizing the newer and more sensitive Generation III devices should be conducted.

This document reports research undertaken at the US Army Natick Research, Development and Engineering Center and has been assigned No. NATICK/TR-90/043 in the series of reports approved for publication.

TABLE 1.

TENTAGE FABRICS USED IN BLACKOUT TESTING

LAB. SAMPLE NO.	DESCRIPTION	USAGE
1.	MIL-C-44103/Coated Polyester Duck/ Camo. Green 483	TEMPER (walls, roof, fly). Standard Integrated Command Post System. (SICPS) (walls) Marine Corps General Purpose Tents.
2.	MIL-C-44103/Coated Polyester Duck/ Tan 459	TEMPER (walls, roof, fly).
3.	MIL-C-43627/Cotton Duck/ OD-7	All standard General Purpose type tents.
4.	MIL-C-43285/Hypalon® Coated Polyester Duck/ OD-7/Pale Green	Air Supported tents, truck covers, ground skirts, tent connectors, floors - TEMPER and SICPS.
5.	MIL-C-20696/Coated Nylon/ "Green"/"Green"	SICPS (roof), Truck covers, Tarpaulins.
6.	MIL-C-43285/Hypalon® coated/Polyester Duck/ Tan 459/Pale Green	Air Supported tents, truck covers, ground skirts, tent connectors, floors - TEMPER and SICPS.
7.	MIL-C-43006/Coated Polyester/ Camo. Green 483/White	Tent Covers, SICPS Roof Liner, under consideration as tent liner.
9.	Graniteville Experimental SPS-62-88/Tan/Black	----------------------
16.	NBC Protective Film Green/Green	Marine Corps Portable Collective Protection System (PCPS). Tarpaulins.

TABLE 2
LABORATORY AND FIELD BLACKOUT TEST RESULTS
FOR TENTAGE FABRICS

LAB. SAMPLE NO.	DESCRIPTION	LABORATORY MEASUREMENT: PHOTOPIC VISIBLE (VIS) FT.-LAMBERTS	LABORATORY MEASUREMENT: OPEN WATTS Cm^2/ST	RANKING (1 IS BEST) LABORATORY: PHOTOPIC (VIS)	RANKING LABORATORY: OPEN	RANKING FIELD: (VIS)	RANKING FIELD: I^2
1.	MIL-C-44103/Coated Polyester Duck/ Camo. Green 483	0.002	6.030	3	5	3	**
2.	MIL-C-44103/Coated Polyester Duck/ Tan 459	2.500	51.700	7	7	6	6
3.	MIL-C-43627/Cotton DUCK/OD-7	0.001	3.840	2	4	2	**
4.	MIL-C-43285/Hypalon Coated Polyester Duck/ OD-7/Pale Green	0.001	0.002	1	1	1	1
5.	MIL-C-20696/Coated Nylon "Green"/"Green"	0.021	0.510	4	2	4	**
6.	MIL-C-43285/Hypalon coated/Polyester Duck/ Tan 459/Pale Green	0.001	0.014	1	1	1	1
7.	MIL-C-43006/Coated Polyester/ Camo. Green 483/White	5.000	178.000	8	8	7	6 or 7
9.	Graniteville Experimental SPS-62-88/Tan/Black	0.156	3.400	5	3	5	**
16.	NBC Protective Film Green/Green	0.542	12.100	6	6	--	**

* IMAGE INTENSIFIER
** DISAGREEMENT EXISTS ABOUT THE RANKING

TABLE 3
RESULTS FROM OBSERVERS

Y = Yes, could detect with light on
N = No, could not detect with light on

LAB SAMPLE NO.	DISTANCE	VISIBLE		IMAGE INTENSIFIER	
		BRUCE LAMP	INCANDESCENT	BRUCE LAMP	INCANDESCENT
1	25 meters	Yes (Y)	Y	Y	Y
	50	Y	Y	Y	Y
	100	Y	Y	Y	Y
	150	Y	Y	Y	Y
	200	No (N)	Y-N (2Y, 2N)	Y	Y
	300	N	N (3N, 1Y)	Y	Y
2	25	Y	Y	Y	Y
	50	Y	Y	Y	Y
	100	Y	Y	Y	Y
	150	Y	Y	Y	Y
	200	Y	Y	Y	Y
	300	Y	Y	Y	Y
3	25	N	N	Y	Y
	50	N	N	Y	Y
	100	N	N	Y	Y
	150	N	N	Y	Y
	200	N	N	Y	Y
	300	N	N	Y	Y
4	25	N	N	N	N
	50	N	N	N	N
	100	N	N	N	N
	150	N	N	N	N
	200	N	N	N	N
	300	N	N	N	N
5	25	Y	Y	Y	Y
	50	Y	Y	Y	Y
	100	Y	Y	Y	Y
	150	Y	Y	Y	Y
	200	N	Y	Y	Y
	300	N (2N,1Y)	Y (2Y,1N)	Y	Y
6	25	N	N	N	N
	50	N	N	N	N
	100	N	N	N	N
	150	N	N	N	N
	200	N	N	N	N
	300	N	N	N	N
7	25	Y	Y	Y	Y
	50	Y	Y	Y	Y
	100	Y	Y	Y	Y
	150	Y	Y	Y	Y
	200	Y	Y	Y	Y
	300	Y	Y	Y	Y

TABLE 3 (CONT'D)
RESULTS FROM OBSERVERS

Y = Yes, could detect with light on
N = No, could not detect with light on

LAB SAMPLE NO.	DISTANCE	VISIBLE		IMAGE INTENSIFIER	
		BRUCE LAMP	INCANDESCENT	BRUCE LAMP	INCANDESCENT
9	25	Y	Y	Y	Y
	50	Y	Y	Y	Y
	100	Y	Y	Y	Y
	150	Y	Y	Y	Y
	200	Y	Y	Y	Y
	300	Y	Y	Y	Y
16	25	Y	Y	Y	Y
	50	Y	Y	Y	Y
	100	Y	Y	Y	Y
	150	Y	Y	Y	Y
	200	Y	Y	Y	Y
	300	Y	Y	Y	Y

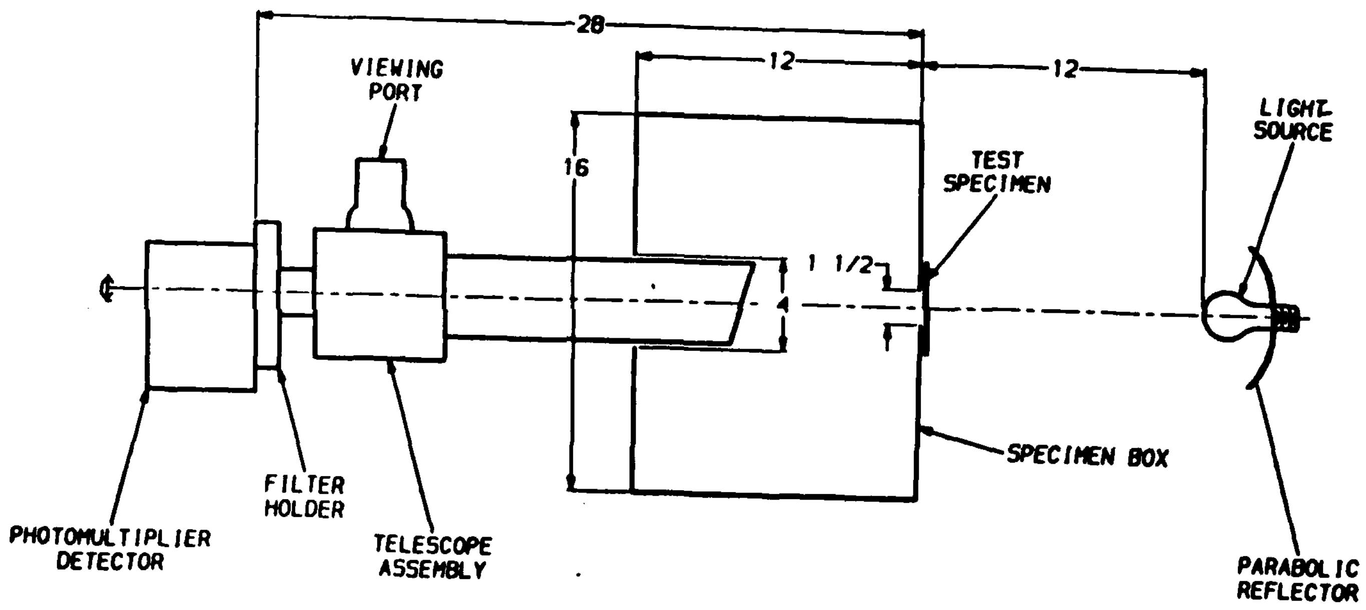

FIGURE 1

PHOTOMETER EXPERIMENTAL ARRANGEMENT

OBSERVER
SAMPLE DATA SHEET

OBSERVER____________________ TEST MATERIAL____________

DATE__________ TIME_________ SKY CONDITION____________

LOCATION____________________ LUNAR CONDITION__________

DISTANCE	VISUAL B	VISUAL I	REFLECTANCE	IMAGE INTENSIFIER B	IMAGE INTENSIFIER I	GLOSS COMMENTS
25 m						
50 m						
100 m						
150 m						
200 m						
300 m						

Visual y= detect light
n= unable to detect

Reflectance with Lights off
1 = darker than background
2 = equal to background
3 = brighter than background

Image Intensifier
0 = not visible
1 = dim image
2 = bright image

Bruce Lamp = B
Incandescent = I

Figure 2. Observer Sample Data Sheet

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